# Balancing Efficiency and Fairness in Blockchain: A Proof-of-Useful-Work-Based BlockChain Consensus Protocol

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Proof-of-Useful-Work (PoUW)-based blockchain consensus protocols become very popular because they enable increasing the energy efficiency of blockchain systems [1,2]. Among the examples of useful work, Combinatorial Optimization (CO) problems [3] and Artificial Intelligence (AI) techniques [4] are particularly used. Besides being the objective of useful work, AI can be used as a tool for improving the performance of blockchain system. As an example, this study explores how AI, particularly Machine Learning (ML) and Reinforcement Learning (RL), can be utilized to improve PoUW proposed in [3,5]. The current protocol addresses fairness and efficiency by controlling the difficulty of CO tasks that miners must solve. However, manually determining the appropriate difficulty levels for different miners can lead to suboptimal resource distribution and delays in consensus. AI offers a promising solution to these challenges by automating task difficulty adjustment and optimizing miner performance.

ML algorithms could be employed to predict the difficulty of CO problems, enabling the system to dynamically assign tasks based on a miner's historical performance, computational power, and available resources. By creating models that learn from past mining data, the system can more accurately predict the time required to solve certain tasks, leading to better workload balancing across the network. Such an approach reduces redundancy, as miners are more likely to receive tasks suited to their capabilities, thereby improving overall network efficiency and reducing energy consumption.

RL offers additional potential for optimizing miner's strategies. By employing RL, miners can adapt their task selection and problem-solving techniques based on feedback from the network, such as success rates or block discovery probabilities. Over time, these algorithms can learn which strategies maximize their rewards, leading to more efficient task allocation and faster block production. In addition, AI could enhance the system's adaptability to varying network conditions. For example, during periods of high congestion or low participation, AI models could dynamically adjust the task difficulty or even modify the reward mechanisms to incentivize miners. This adaptability helps maintain the stability and efficiency of the blockchain, regardless of fluctuating network activity.

This study discusses potential AI-driven solutions and highlights the benefits of incorporating machine learning and reinforcement learning into the existing framework to ensure fairness, scalability, and sustainability in blockchain consensus mechanisms. To evaluate the effectiveness of the proposed protocol, we are developing a simulation framework that models behavior of miners and clients, task distributions, and realization of consensus protocol under various network conditions. This simulation enables us to test the adaptive task difficulty adjustments and miner optimization strategies in a controlled environment. By simulating different network scenarios, we can observe how AI-enhanced task assignment impacts energy efficiency, fairness, and overall network throughput. Our preliminary results show that integrating AI techniques into PoUW-based blockchain protocols has the potential to significantly enhance the efficiency of task allocation, miners' optimization strategies, and the overall system performance.

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